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High Voltage, High Side Driver for Electronic Lamp Ballast Applications

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INTRODUCTION

As electronic ballasts continue to displace their old core and coil predecessors, we see increased emphasis being placed upon cost reduction, reduced part count, and overall simplification of designs. Motorola's new MPIC2151 Self Oscillating Half–Bridge Driver was developed to simplify electronic ballast designs, using Mos gated output switches in a half–bridge configuration.

The MPIC2151 is just one in a family of monolithic High Voltage Integrated Circuits (HVICs) from Motorola, which offer "single chip" solutions to drive problems which involve interfacing control logic to the high voltage output stage. These HVICs will accept ground referenced input signals and produce high and low side drive outputs, capable of driving either MOSFET or IGBT gates.

The MPIC2151 offers a floating channel high side driver, designed for boot strap operation in applications with a positive rail up to 600 volts. It also contains the low side driver output for the bottom switch in the half–bridge. Other features of the MPIC2151 include the provision for programmable oscillator frequency and under voltage lock out protection.

THEORY OF OPERATION

We will begin by discussing the functional block diagram of the MPIC2151, see Figure 1.

The MPIC2151 is intended to be powered from the rectified A–C line voltage, through a low wattage, high resistance dropping resistor to the V_{CC} pin. This HVIC has an internal zener clamp between V_{CC} (pin 1) and Common (pin 4) which regulates at a nominal 15.6 volts. This requires typically less than 5 mA of current through the dropping resistor to regulate the voltage to the "on–board" circuitry.

The front end of the MPIC2151 operates much like a conventional CMOS 555 timer and can be configured for either synchronized running or self oscillation, with the addition of external R_T (pin 2) and C_T (pin 3) components. When used in the self oscillating mode, the frequency of operation can be stated by:

$$f_{osc} = \frac{1}{1.4(R_T * C_T)}$$

The MPIC2151 has internal circuitry which provides for a nominal 1.2 μs dead time between the High Output (pin 7) and the Low Output (pin 5). This is intended to minimize the possibility of both power switches being in conduction at the same time. It is also important to note that the R_T (pin 2) and L_O (pin 5) are in phase with each other.

The propagation delays for the outputs H_O and L_O are matched in order to simplify 50% duty cycle operation. This is taken care of by internal design features of the MPIC2151.

Finally, the High output (pin 7) can be used to drive an N–channel MOSFET or an IGBT as the upper switch in a half bridge circuit. This output is not referenced to Common, instead it gets its reference through V_S (pin 6) to the mid–point of the half bridge. The MPIC2151 will operate in rail conditions from 10 – 600 Vdc.

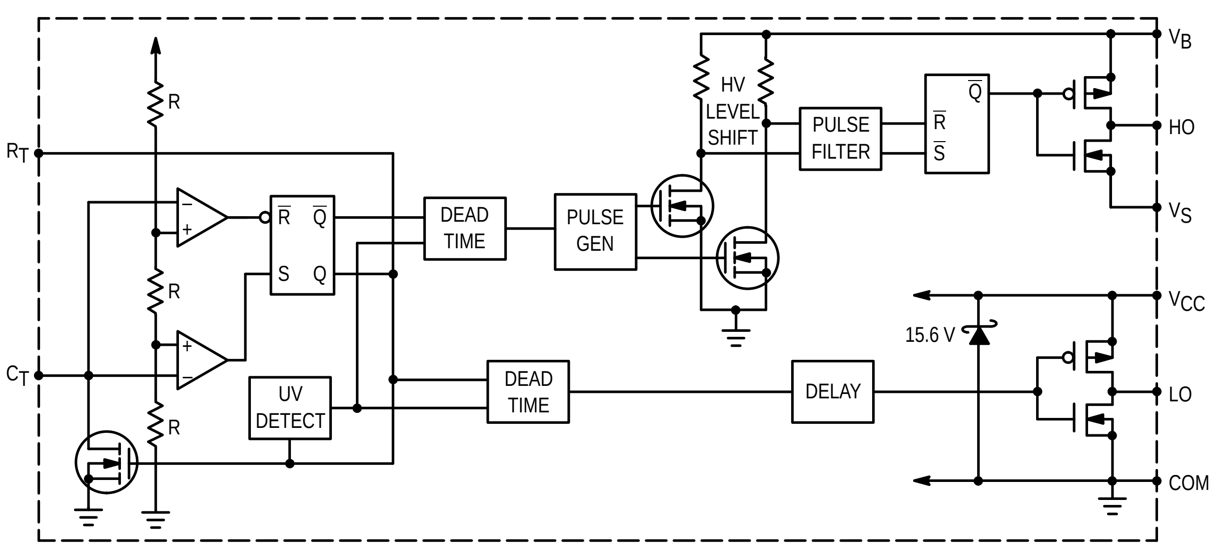

Figure 1.

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APPLICATION

One example of a lamp ballast circuit application for the MPIC2151 is the self oscillant, half bridge topology employed in most compact fluorescent lamp products. The half bridge configuration offers the most advantages with lower voltage componants for a given line voltage and therefore, lower system cost. Generally speaking, galvanic isolation is not a consideration in this application (1).

The demonstration circuit in Figure 2 is an example of a compact fluorescent lamp, powered from 230 Vac mains. The rectified DC buss voltage will be approximately 320 Vdc and the component values were selected for applications up to 20 watts.

This circuit is greatly simplified by the MPIC2151, as there is no need for the conventional diac start–up circuitry and the space consuming saturable transformer normally used to produce the gate drive. This allows for a more compact, lighter weight ballast. It should be noted that the circuit density can be further increased by the use of surface mounted components.

Lay Out

When designing with the MPIC2151, there are some considerations to be observed in the begining. This will help to avoid many of the “pit falls” which may require attention after the circuit has been assembled.

First, proper layout of the circuit board is critical. Noise can interfere with the operation of the control circuitry, causing erratic operation or misfiring of the power devices. It is important to minimize stray inductances along the main current loop, as these can cause very fast high voltage spikes to occur.

Second, Use high frequency de–coupling techniques in the power stage to minimize the effects of stray capacitance.

Third, use series gate resistors (see R_3 and R_4) to control the turn off speed (Dv/Dt) of the power devices.

Fourth, the physical location of the bootstrap capacitor must be placed as close to the HVIC V_B and V_S leads as practical. This further helps to keep the stray inductance on the V_S lead to a minimum.

And finally, when looking for noise spikes, probe at the MPIC2151 lead itself. Looking further away may not give an accurate indication of the total effects of the stray inductance (2).

Selecting the Dropping Resistor Value

In the self oscillating mode, the MPIC2151 self starts when the high voltage dropping resistor R_1 charges the I_C supply filter capacitor C_2 to a value above the HVICs internal Under Voltage Lock–Out threshold ($V_{ccuv}+$ = 8.4 volts typical). The output of the half bridge then oscillates at a frequency determined by the timing components R_T and C_T (with a 50% duty cycle).

Selecting the correct value for the dropping resistor is accomplished by taking into account the total current requirements for the HVIC and surrounding components. These include:

1. The current required to regulate V_{CC} through the internal zener clamp from V_{CC} (pin 1) to Common (pin 4).
2. The current required to switch the gates of the power MOSFETs or IGBTs.
3. The quiescent current I_{qcc} of the MPIC2151.
4. The high voltage level shifting currents within the HVIC.
5. The current sourced into the R_T resistor from the chip V_{CC} (3).

Obviously, the largest component of current is that for the zener clamp. Generally speaking, the “rule of thumb” solution for R_1 can be expressed by:

$$R_1 = \frac{(V_{buss} - 15.6\ \text{volts})}{(I_{CC} \times \kappa)}$$

Where: **V_{buss}** = the rectified DC value of the AC line voltage, **15.6 volts** is the nominal internal clamp voltage, **I_{CC}** (from the MPIC2151 data sheet = 5 mA nominal), κ = 1.30 to 1.40 multiplier to provide sufficient current for the other circuit elements, over the expected operating temperature range.

$$R_1 = \frac{(320 - 15.6)}{(6.48) \times 10^{-3}} = 47\ \text{k}\Omega$$

In our schematic example, V_{buss} = 320 Vdc, V_{clamp} = 15.6 V, I_{CC} = 5 mA, plus 30% = 1.48 mA, and R_1 = 47 kΩ. Also, it should be noted that C_2 should be sufficiently large that it does not become discharged during normal circuit operation. The value we selected in our example is a 47 µF electrolytic capacitor.

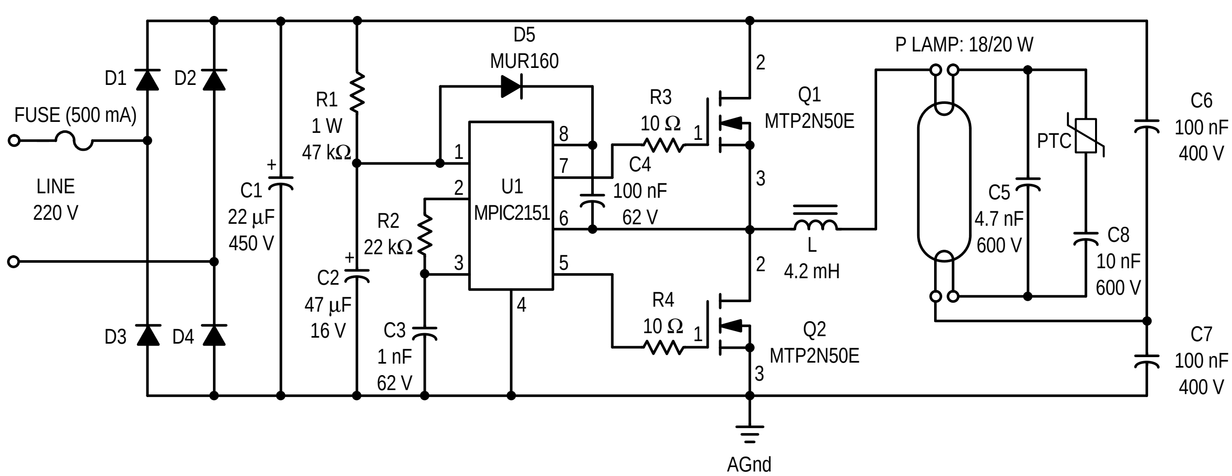

Figure 2.

Once the lamp has struck, aided with the high voltage pulses developed by the starting network (L, C_5, C_8, and the PTC), the lamp operates at the resonant frequency defined by the L–C tank circuit formed mainly by the inductor L and C_6, C_7 in parallel. Therefore, the values of R_2 (R_T) and C_3 (C_T) are selected to set the output frequency of the MPIC2151 slightly above or below the F_0 of the tank circuit. The output of Q_1 and Q_2 will be a 160 volt RMS square wave at 50% duty cycle.

Recommended Board Layout

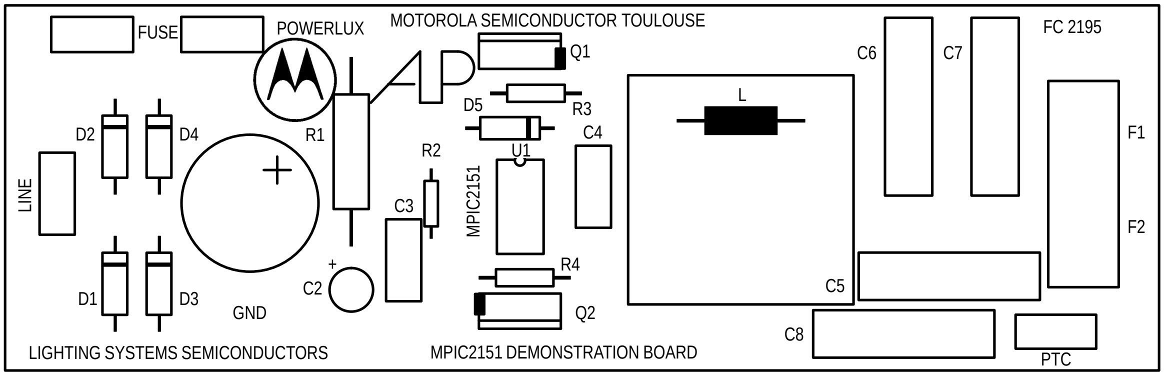

Figure 3. (Top View)

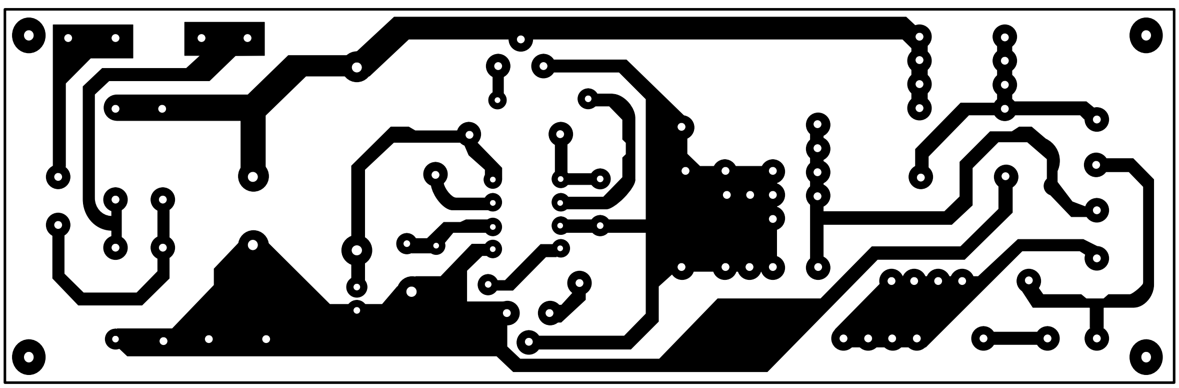

Figure 4. (Bottom View)

Parts List

C_1	22 µF / 450 V / electrolytic	R_1	47 kΩ
C_2	47 µF / 25 V / electrolytic	R_2	22 kΩ
C_3	1 nF / 63 V / ceramic	R_3, R_4	10 Ω
C_4	100 nF / 63 V / ceramic	L	4.2 mH
C_5	4.7 nF / 1000 V / polypropylene	Lamp	18 – 20 W Compact Fluorescent
C_6, C_7	100 nF / 400 V	Q_1, Q_2	MTP2N50E
C_8	10 nF / 1000 V		
D_1, D_2, D_3, D_4	1N4007		
D_5	MUR160		

Notes: All resistors are ±5%, 0.25 watt unless otherwise noted.
All capacitors are polycarbonate, 63 V, ±10% unless otherwise noted.

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